

## **6.2-6.4 RDT&E Reviews**

### **06-08 March 2012**

### **Stennis Space Center, MS**

#### **Project: Modeling Sensing and Forecasting Ocean Optical Products for Navy Systems**

PI: Sherwin Ladner

Email: [ladner@nrlssc.navy.mil](mailto:ladner@nrlssc.navy.mil)

Phone: 228-688-5754

**Performers: B. Arnone, J. Joliff, A. Weidemann, S. Derada, A. Quaid - NRL**  
**B. Casey - QNA**

**Customer POCs – Ken Grembowicz, K. Matulewski, P. Lyon, P. Flynn - NAVO**



# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems



## Objectives

Provide naval operations with a real time and forecast characterization of the battlespace used to produce warfare performance surface for ocean optical and visible detection

1. Forecast coastal ocean optical properties including water clarity, horizontal and vertical visibility for visual detection vulnerability and lidar penetration depth (ALMDS).
2. 3D optical volume (nowcast/forecast) derived by assimilating gliders, satellite and ocean models to define the 3d optical structure.
3. Performance surfaces supporting underwater laser imaging systems (AQS/EODES), airborne laser systems (ALMDS), active and passive EO bathy systems, and diver operations (visibility/vulnerability).

**FY11/12**

## Accomplishments/Challenges/Issues

1. Fleet MIW Demonstration/Evaluation of TODS Components & AQS-24 Performance Surfaces during Vulcanex 11-1 in Panama City with HM-14, NOMWC, AWSTS, NSA PC, NSW PC. (NRL/NAVO Glider Operations) - NGOM Test Bed
2. Transitioned TODS OpCast v2.0 to NP3. VTR/OPTTEST Completed.
3. Development and integration of new 3D advection software (BioCast) into TODS Completed / Validation Underway
4. 3D BioCast (v1.0) surface forecast testing/automation completed using multiple satellite and model resolutions:
  - MODIS 1km / RELO-NCOM AMSEAS (NAVO) 3km for MissBight / NGOM test bed - 24 hour forecast at 3 hour time steps. Initial comparisons with OpCast v2.0 (Real-time since Sep. 2011)
  - MODIS 250m / RELO-NCOM chesapeake\_miw (NAVO) 500m for Chesapeake Bay - 48 hour forecast at 1 hour time steps. (3 month sequence Sep. 01 - Nov. 28, 2011)
  - HICO 100m / RELO-NCOM chesapeake\_miw (NAVO) 500m for Chesapeake Bay - 24 hour forecast at 1 hour time steps. (1 Day)
  - GOCI 500m / RELO-NCOM wpac\_2 (NAVO) 3km for Yellow Sea - 7 hour forecast at 1 hour time steps (1 Day) w/ validation

## Requirements and Capabilities

CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 Hi Res Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare and predict and forecast the 2D/3D optical environment

- Fusion of environment data for impact assessments
- 4 d coherent picture of the coastal environment
- (Naval Capability Based Assessment for oceanography for 21<sup>st</sup> Century EXW) Oct 2009)
- TACMEMO under development for performance surface for active EO Identification CNO(N841A) 762-0601; 16 October 2009
- METOC Environment Initial Capabilities Document (ICD) define performance field for MIW imaging system

**Funding**

(\$K)	FY11	FY12	FY13	FY14
J PSS - cal val	180	200	200	200
6.2 Subsurface Optics	630	565		
6.2 Algorithm ensemble	500	500	500	
<b>Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems</b>	<b>300</b>	<b>150</b>	<b>365</b>	<b>200</b>



# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems

## Project Schedule With Major Deliverables



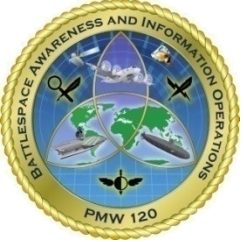
Tactical Ocean Display System (TODS)																				
	FY11				FY12				FY13				FY14				FY15			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
(1) Forecast Optical Properties (OpCast-2D FY11 / BioCast-3D FY12)			<b>O</b>	<b>V</b>			<b>V</b>	<b>O</b>								<b>V</b>	<b>O</b>			
(2) 3D Optical Nowcast (3DOG) w/ AQS-24 System Performance												<b>V</b>	<b>O</b>							
(3) Exercises / Demonstrations			<b>D</b>			<b>D</b>					<b>D</b>			<b>D</b>						

Milestones indicate **V**TR panel-accepted and **O**PTTEST

OpCast v1.0: 100% complete, OPTTEST completed 4QFY11

BioCast v2.0: 60% complete , Planned Transition / VTR 3/4QFY12, Possible delay due to MIW asset / optical glider availability in planned exercise.

3DOG v1.0: 35% complete, Planned Transition / VTR Q4FY13

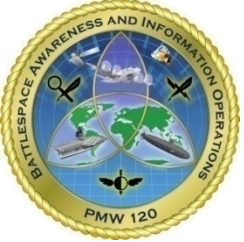


# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems



## Transition Plan Summary

- **4. SUMMARY CONOPS:** The TODS system and its components will reside with NP33 at the Naval Oceanographic Office and will automatically produce near real time high resolution fused and integrated oceanographic products supporting a variety of Navy missions. TODS will be used to support MIW exercises and operations but in the out years could support a variety of Navy missions (NSW, ISR, ASW and EXW). TODS currently provides 2D optical forecasts out to 48 hours. Once all the components of TODS are transitioned, it will provide 3D optical forecasts and MIW system performance products out to 48 hours. These products will be provided to the customer via many avenues (NEP-OC, email, possibly NGDS). *POC Kenneth Matulewski (NP33)*
- **5. CAPABILITY REQUIREMENTS BASIS:** This project supports CNO validated requirements CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 High Resolution Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare.
- **6. INPUTS:** Satellite ocean color imagery (MODIS-Terra, MODIS-Aqua, MERIS, GOCI, and future JPSS), physical and optical glider data (quality controlled), BSP/AEP data, and numerical models (NCOM, RELO).
- **7. OUTPUTS / PRODUCTS:** Outputs from these transitions will advance and deliver near real time high resolution fused and integrated oceanographic products which can be used to support a variety Navy missions especially MIW, and perhaps others. The products include 1) a 2D/3D forecast of coastal ocean optical properties for the performance surface. 2) a performance surface of the laser imaging systems (such as the AN/AQS-24) 3) swimmer performance surface (visibility and vulnerability) 4) performance surface for laser system (eg. ALMDS), and 5) a performance surface for deployment of active and passive EO bathymetry systems (CHARTS).
- **9. ACCEPTANCE CRITERIA:** Systems must go through TECHEVAL at NRL and the resulting VTR must be acceptable to NAVO, then it must pass OPEVAL at NAVO. TECHEVAL will take place at NRL and be demonstrated during fleet MIW exercises. Validation Test Reports (VTR's) will be provided. VTR's will include validation using glider data and TODS' outputs during real MIW fleet exercises and the Northern Gulf of Mexico Test Bed established in FY11. OPEVAL will involve installing the transitioned software on NAVO systems and testing using required inputs in an operational/automated fashion for a 2 month period and using the system to participate in a fleet exercise. The TECHEVAL should evaluate parameters such as comparing 24 hour forecasts to next day images and comparing profile data not assimilated into TODS to model data. This must include Case II waters. Criteria for acceptance will be 24 hour forecast comparisons with next day imagery and between in situ profiles and modeled profiles.



# TODS Update



## – **MIW Exercise Demonstrations / Testing / Evaluation**

1. VULCANEX 11-1 Panama City, FL (April 2011)
2. TACDEVEX Arabian Gulf (November 2011) – MIW Assets Pulled – No NAVO Glider
3. BOLD ALLIGATOR Onslow Bay (February 2012) – MIW Assets Pulled
4. HAWKEX (March 2012) - Planned

## – **Surface Advection Software Upgrade**

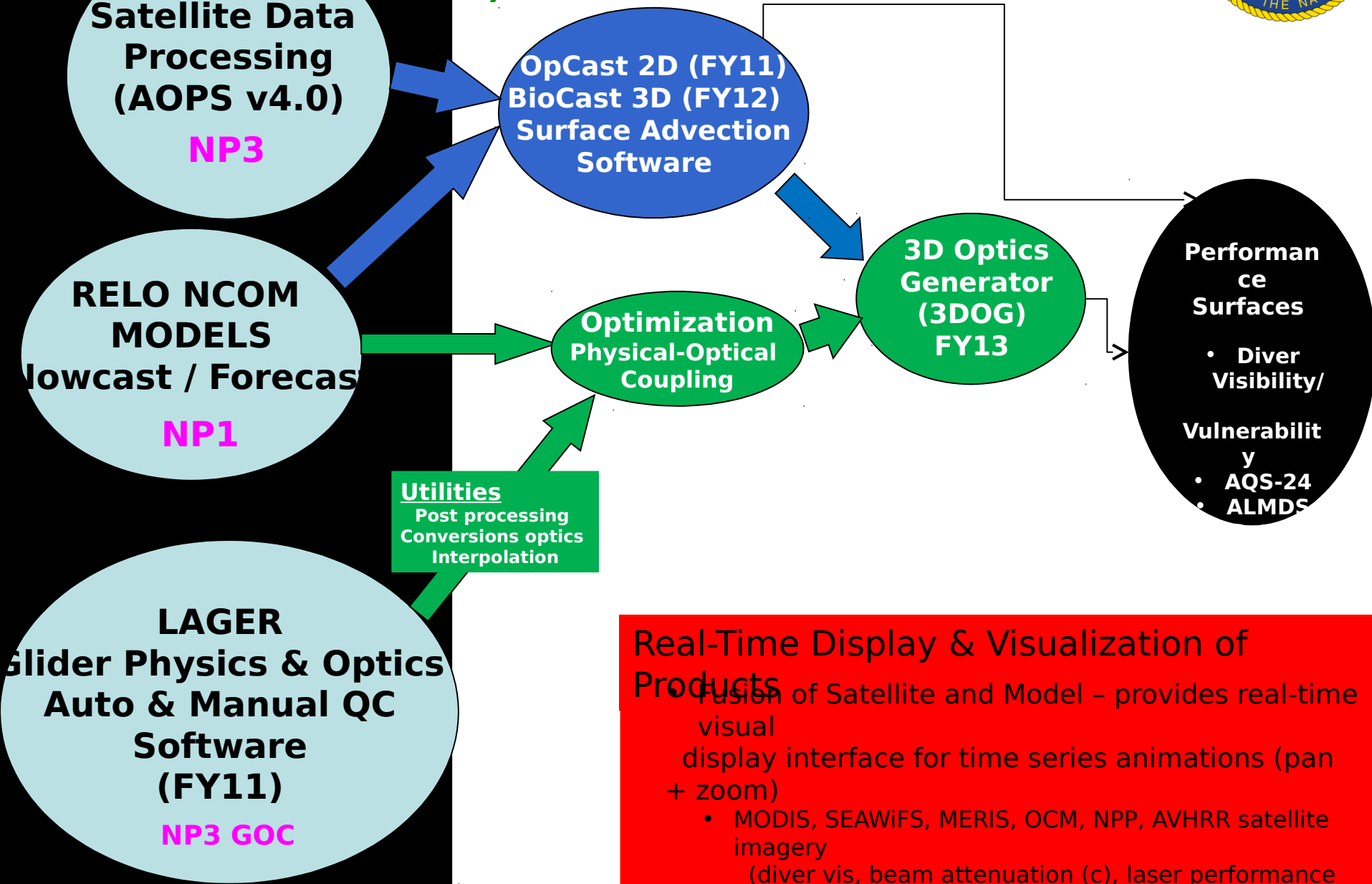
1. Status of BioCast v1.0 (3D Advection Scheme) Upgrade.

# NAVO Operational Inputs

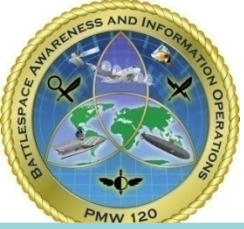
# Components of the TODS



- 1) **Display** 2) **OPCAST 2D / BioCast 3D** 3) **3D and Performance Surfaces**



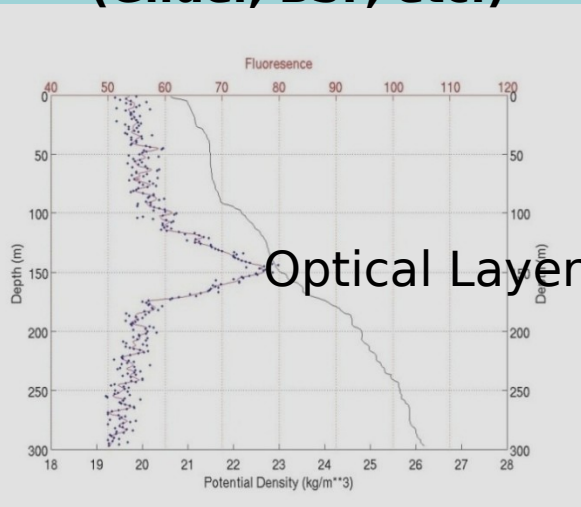




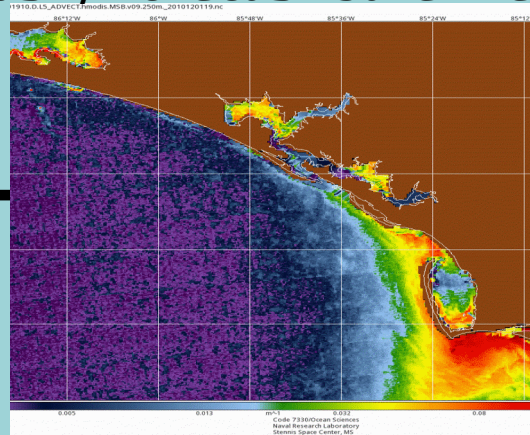
# Fusion of Glider Profiles, Satellite and Numerical Models to support AQS24 Operations



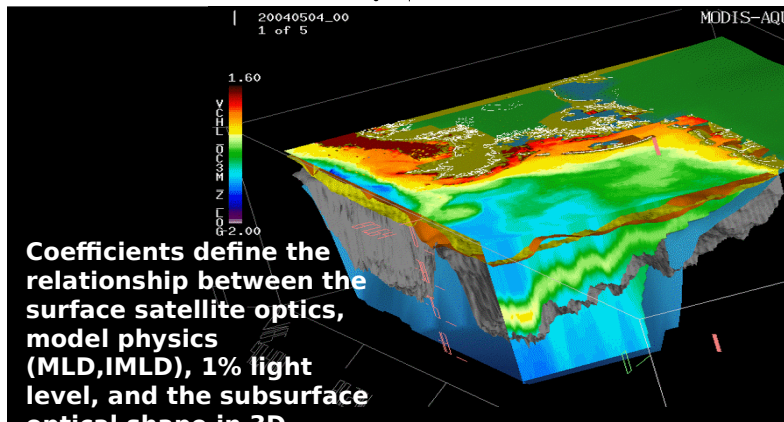
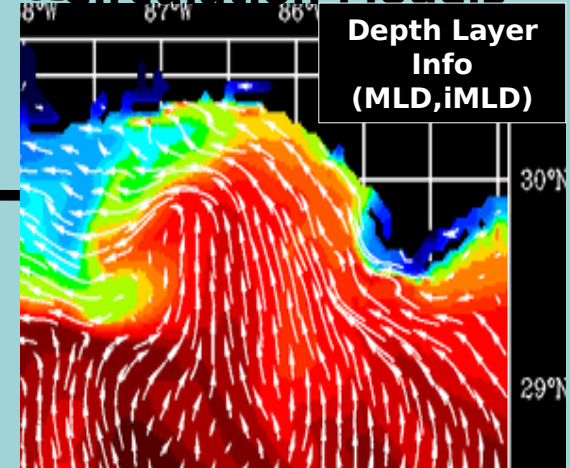
**Vertical Optical Profiles  
(Glider, BSP, etc.)**



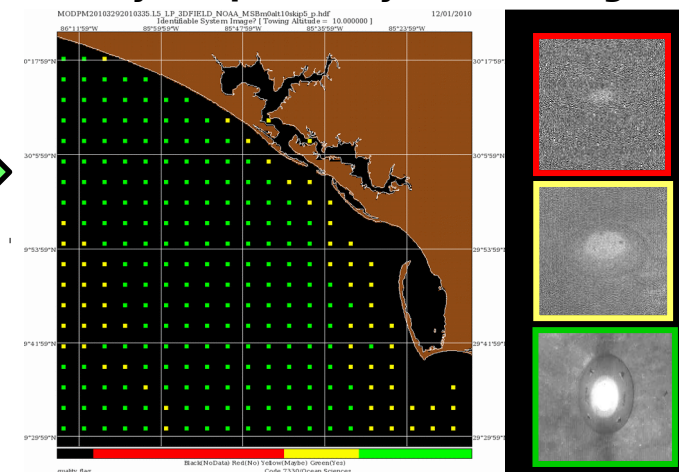
**Nowcast / Forecast Satellite Optics**



**Nowcast / Forecast  
Circulation Models**



**Nowcast/Forecast Performance Surface  
Image Quality & Optimal System Towing Altitude**



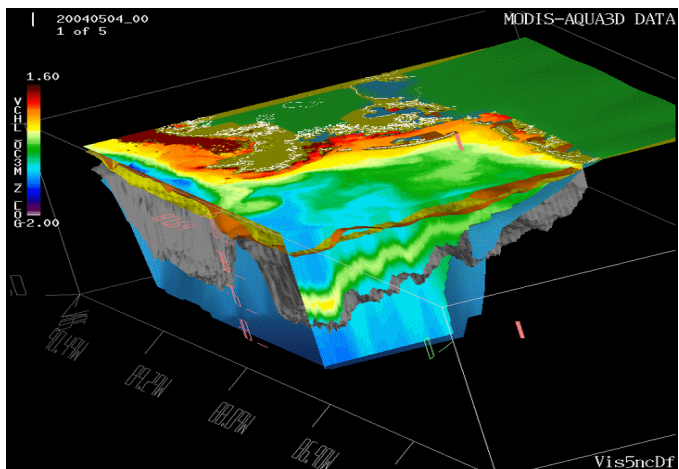
**Optical Volume & 3D Diver Visibility**



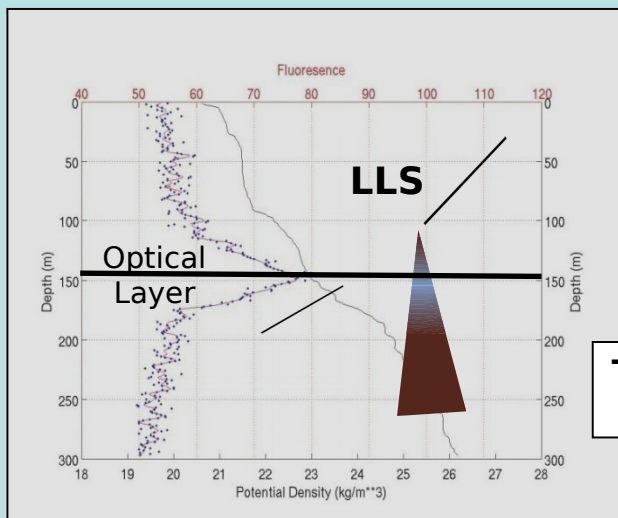
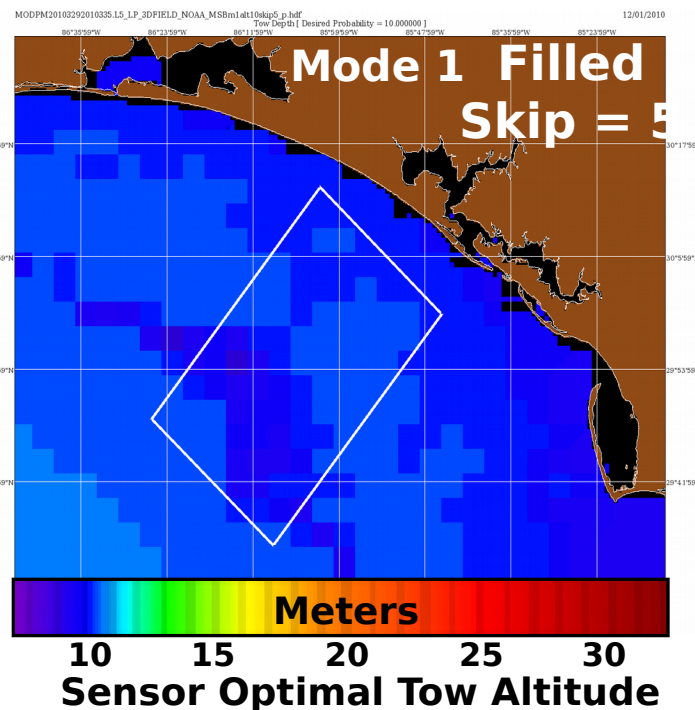
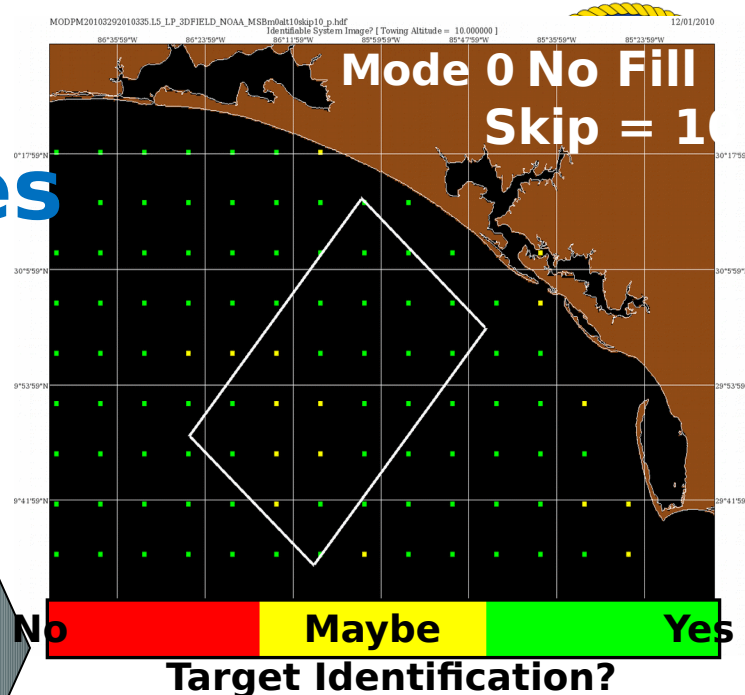
# EO/AQS-24

## Performance Surfaces

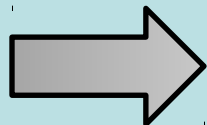
Regional Battlespace Characterization  
3d optical profiles



Regional laser  
imaging  
performance  
(EODES Model)

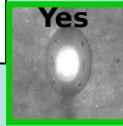
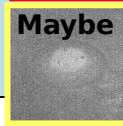


EODES  
Point  
Performance  
(BSP)



Tow **Above/Below**  
Optical Layer

Target ID?







# NRL TODS Fleet Demonstration and Support



## Support provided to HM 14 HARP Exercise

**VULCANEX 11-1 - Panama City, FL - March 30, 2011 - April 08, 2011**

TODS Support (Daily Brief Provided to Fleet):

- a) Nowcast/Forecast (24,48 hours) of the Optical Environment (2D & 3D) ☑ Impact on laser system (ASQ 24) and diver visibility
- b) Nowcast/Forecast (24,48 Hours) 3D Optical Volume / Vertical Optical Layer
- c) Nowcast/Forecast (24,48 Hours) Eoids/AQS-24, ALMDS and diver performance surfaces
- d) Circulation models ☑ 3Km NCOM-RELO
- e) 5,900 optical profiles collected covering 384 km in real-time using Slocum glider for assimilation into 3D Optical Volume (Tuning 3D Model Coefficients and Validation)
- f) End-to-end testing and evaluation of TODS system components (OpCast, 3DOG <- glider optics profiles, performance surfaces <- AQS-24 snipp

### Vulcanex 11-1 HARP Exercise Planning

#### HARP Objectives (AWSTS):

1. Assess the HM squadron's operational capability / level of AMCM combat proficiency
2. Assist in identifying potential problem areas in mission capability.
3. Assist in the tactical training of personnel to increase mission readiness.

Mark J. Reynolds

Technical Systems Integration, Inc.

AMCM Tactics Support & Training

AMCM Weapon Systems Training School

Kevin Oakes

Project Manager

AMCM Tactics Development

NSWC PCD, Code X32 (Tactics Branch)

Beth Branham

Oceanographer/Test and Evaluation

Division Coordination

NSWC PCD

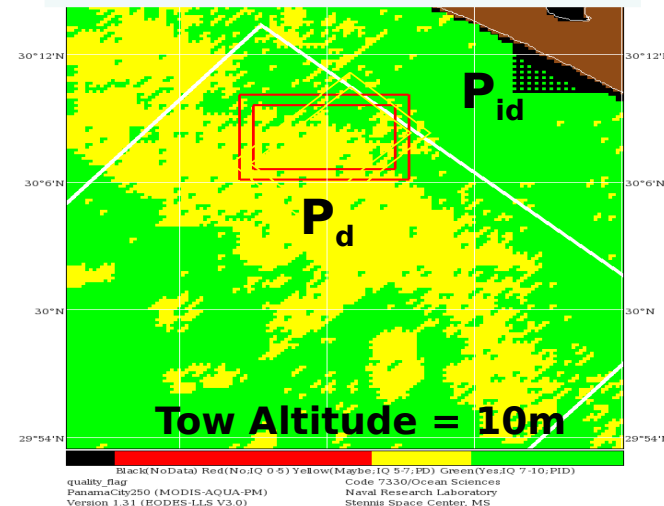
Jeffrey Willows

Op-Area Coordinator (Glider Activity)

Naval Support Activity

NSA PCD, N36

### Eoid Performance Surface

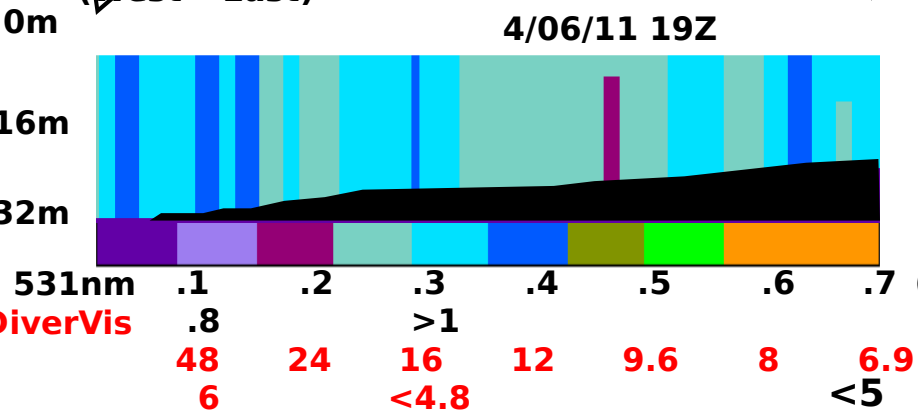
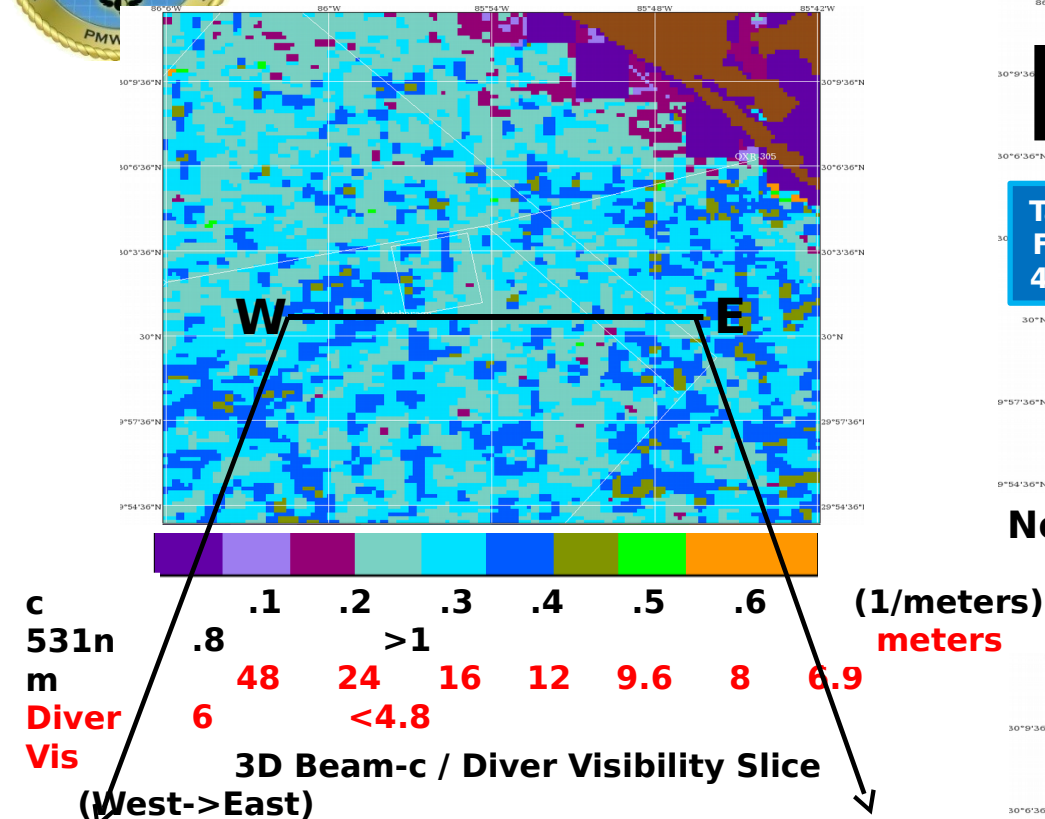




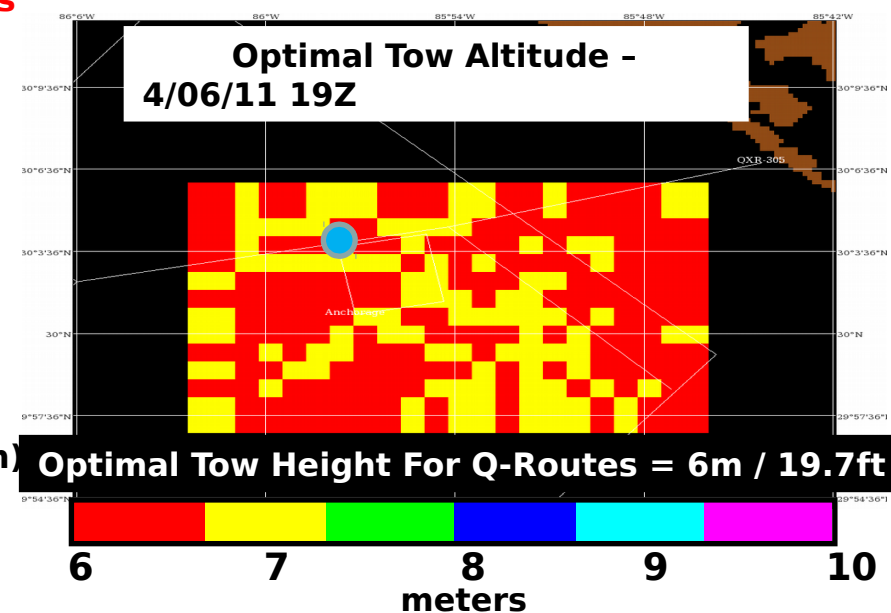
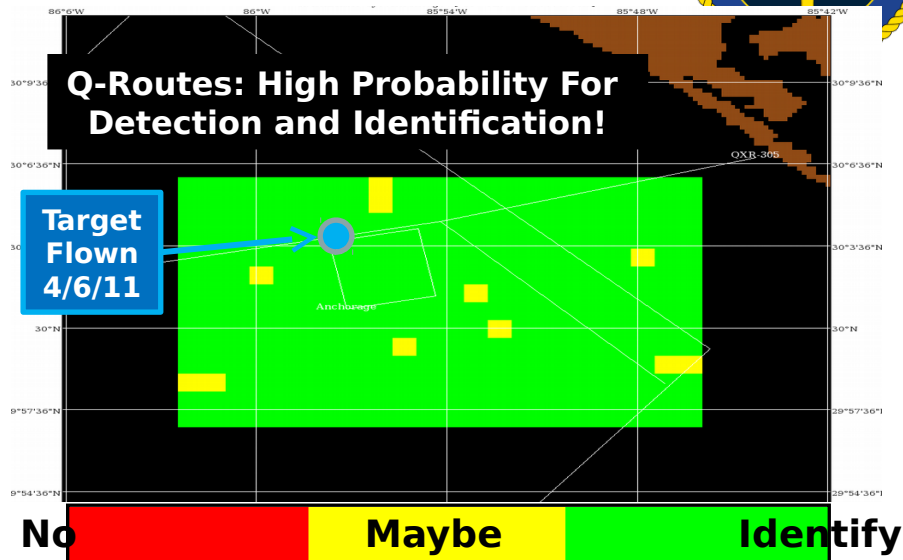
# Exercise Support Products (Nowcast, 24 & 48 Hour Forecast)



## Surface Beam-c / Diver Visibility 4/06/11 19Z



## Target Identification @ 6m/19.7ft Tow Altitude 4/06/11 19Z



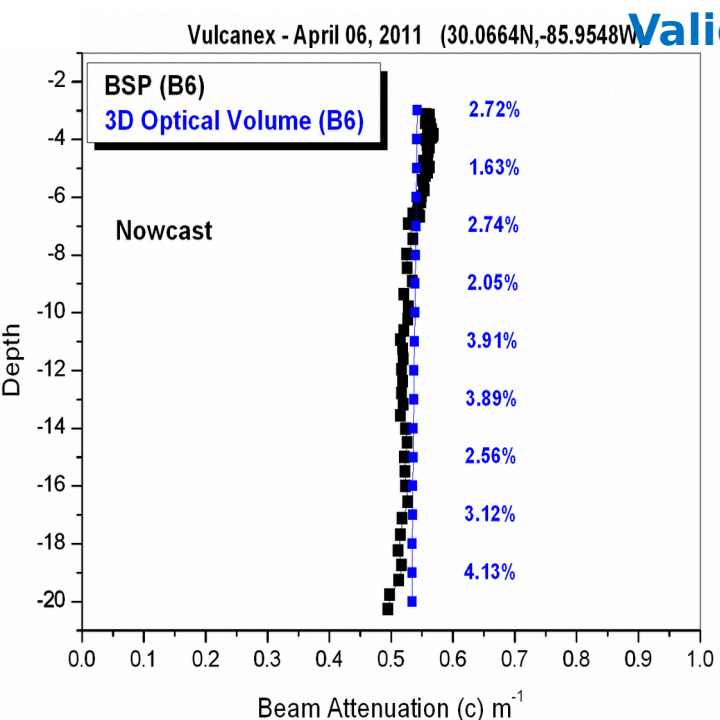
**100% of Mine Targets At Suggested Tow Altitudes Identified!**

# 5-24 HM-14 System Performance Validation - VULCANEX 1

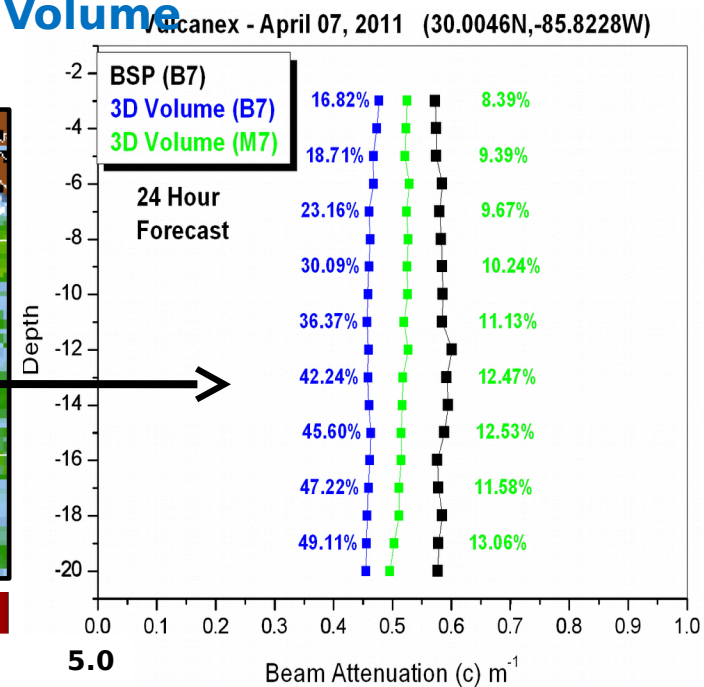
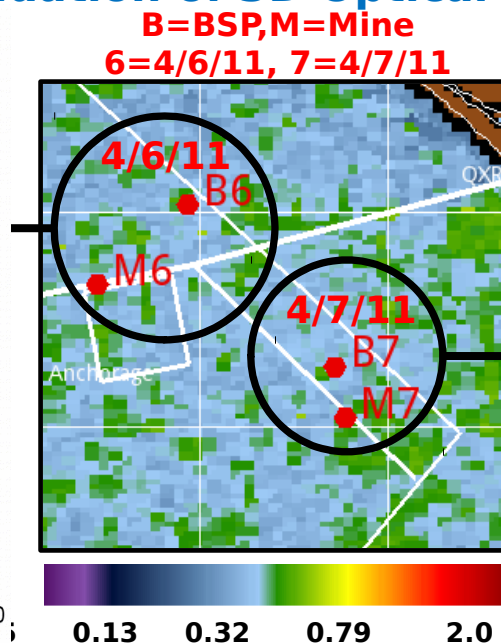
Same Target

STEP 2  
UPS  
3  
4  
STEP 5  
UPS  
6  
7

Actual (HM) and Suggested (NRL,NAVO) Tow Heights										
#	Date	GMT	Mine Type	HM-14	NRL	NAVO	DET	ID		
	4/6	2132	Mk52	20.0 ft	19.7 ft	19.7 ft	YES	YES		
	4/7	2238	Mk52	24.0 ft	22.9 ft	19.7 ft	YES	YES		
	4/7	2256	Mk52	20.0 ft	"	"	YES	YES		
	4/7	2310	Mk52	17.0 ft	"	"	YES	YES		
	4/7	2043	Mk52	17.0 ft	"	"	YES	YES		
	4/7	2050	Mk52	20.0 ft	"	"	YES	YES		
	4/7	2106	Mk52	24.0 ft	"	"	YES	YES		



## Validation of 3D Optical Volume





# Vulcanex AQS-24 System Performance Surface Validation

**Apr 06, 2011 (Newcast)**



ST A	IQR	ID ?	OTA	SNIPPET
7m 22.96ft 4/6/11				
Legends		<p>Yes Maybe No</p>	<p>(m) 20 23 26 29 32 35 (ft)</p>	



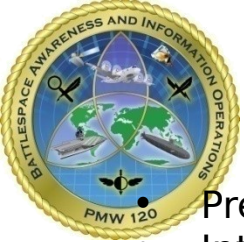


# Volcanex AQS-24 System Performance Surface Validation

## Apr 07, 2011 (24-Hour Forecast) - Step Ups



	IQR	ID?	OTA	SNIPPET
<b>5m</b> <b>16.7ft</b> <b>4/7/11</b>				
<b>6m</b> <b>19.7ft</b> <b>4/7/11</b>				
<b>7m</b> <b>22.96ft</b> <b>4/7/11</b>				
<b>Legends</b>	 0 3 7 11 Bad Good	<b>Yes (IQR 7-10)</b> <b>Maybe (IQR 5-7)</b> <b>No (IQR 1-5)</b>	 6 7 8 9 10 11 (meters)	<b>Note:</b> <b>Loss of Contrast,</b> <b>Size and Detail</b>



# BioCast 3D Advection



- Preliminary comparisons with OpCast show forecast improvement
- Integration into TODS Complete – Drop in replacement OpCast 2+1D Advection Scheme
- Testing and Validation (VTR) underway
- **Transition to NAVO (NP3) w/ VTR FY 12 (Q3)**

## INPUTS:

- Ocean Circulation Model
- Satellite Surface SEED Image or 3D Optical Volume (3DOG)

## OUTPUT:

- Tracer Advection (Hourly)

## OPERATION FLOW:

1. **Adjust Flow Fields to obey continuity and Courant-Friedrichs-Lewy (CFL) stability over the user defined 3D grid and time step.**
2. **Check adjusted flow fields for stability**
3. **Define initial 3D tracer field**
4. **Advect tracer in 3D space using first order upwind differencing scheme**

**Repeat Steps 1-4 at time resolution of physical model output**

5. **Optional – Add sources and sinks to tracer field**



MODIS-Aqua  
1km

OpCast/BioCast  
Comparison

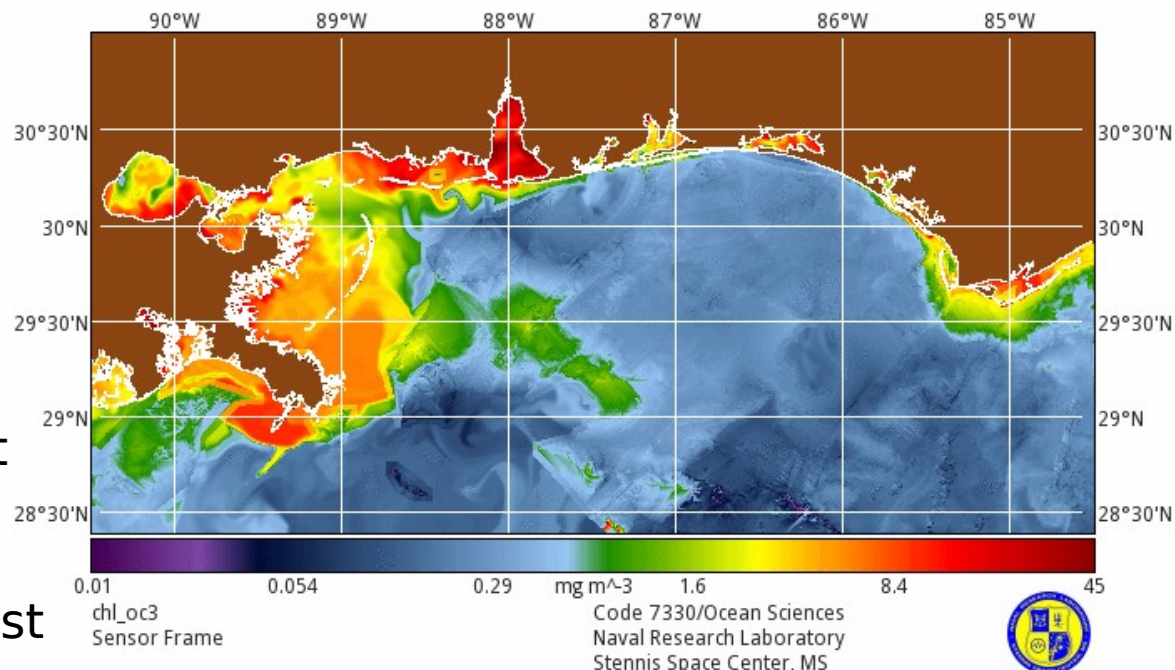
24 Hour Forecast  
Animation

NCOM  
RELO  
(AMSEAS)

Jan 23, 2011  
17?? GMT

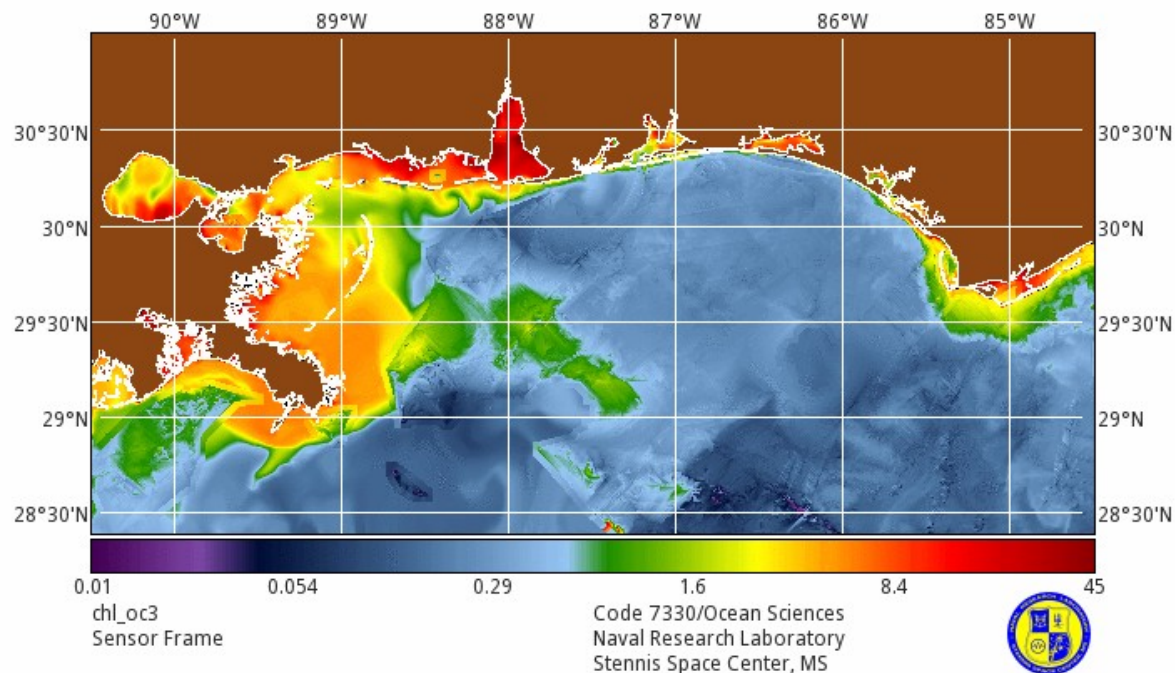
OpCast

01/23/2012(19)



BioCast

01/23/2012(19)







hico\_2011009\_2011010917.nc

Sun Jan 9 17:00:00 2011



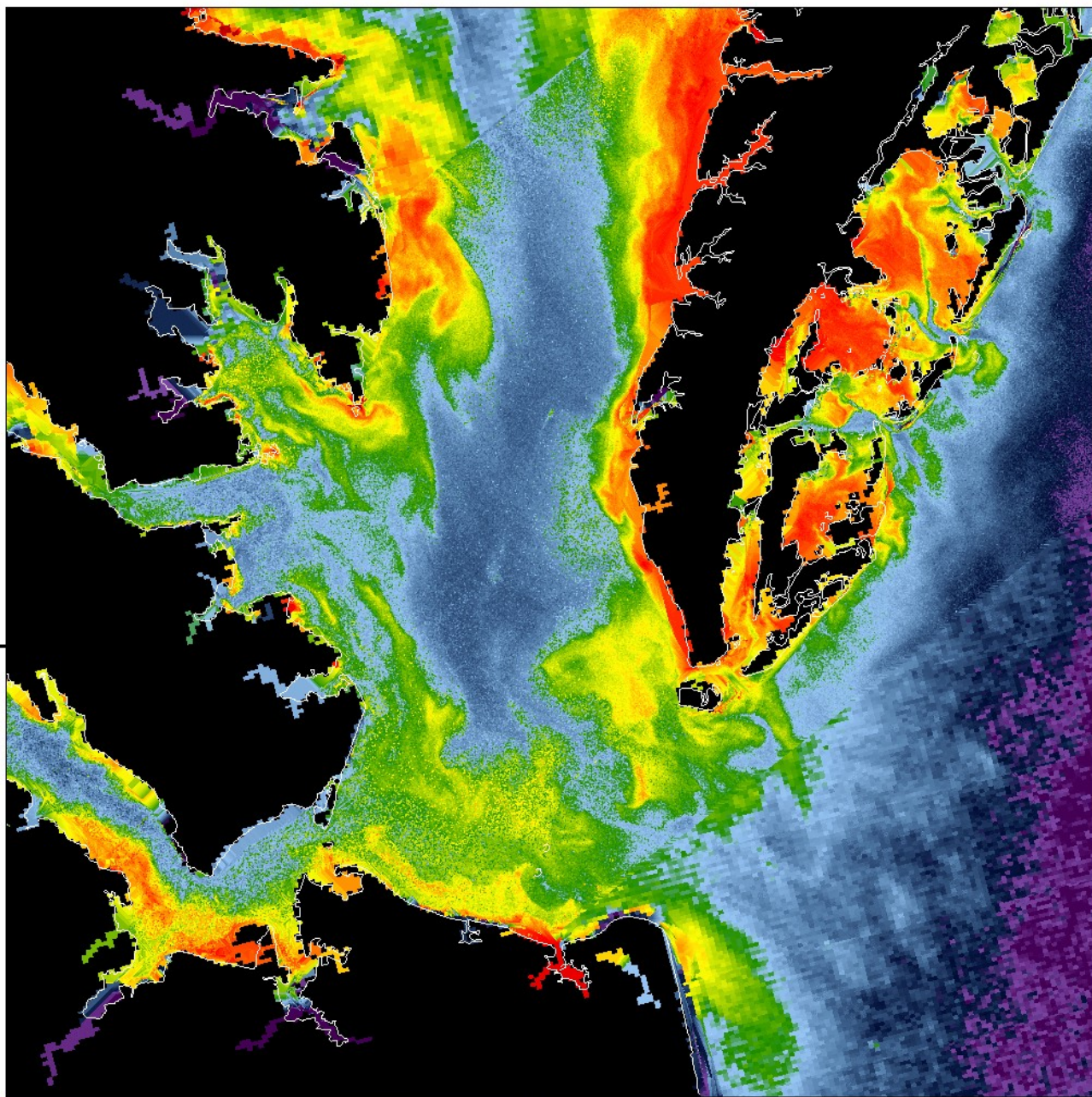
HICO  
100m

BioCast-3D  
Advection

NCOM  
RELO  
(chesapeake\_

Jan 09, 2011  
17?? GMT

Hourly  
Animation



0.006 0.013 0.027 0.056 0.12 0.25

bb\_547\_qaa  
Sensor Frame

Code 7330/Ocean Sciences  
Naval Research Laboratory  
Stennis Space Center, MS





# Hourly Backscattering (bb @555nm)

GMT  
Time

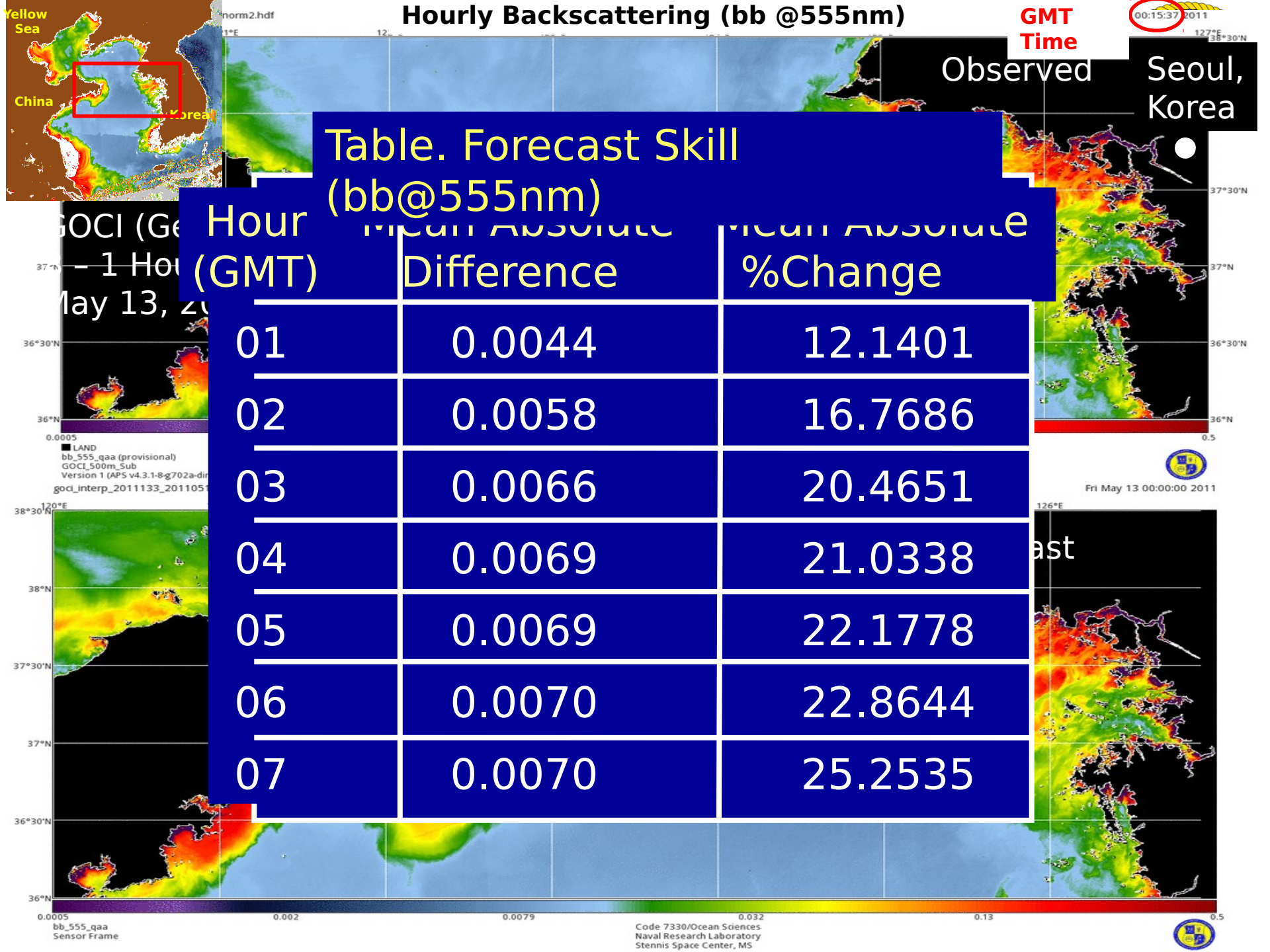
00:15:37 2011

Observed

Seoul,  
Korea

Table. Forecast Skill  
(bb@555nm)

Hour (GMT)	Difference	%Change
01	0.0044	12.1401
02	0.0058	16.7686
03	0.0066	20.4651
04	0.0069	21.0338
05	0.0069	22.1778
06	0.0070	22.8644
07	0.0070	25.2535





# Summary: and Accomplishments

★ = Completed



## **TODS - Surface Advection Software (OpCast-2D, BioCast-3D)**

### **- OpCast v2.0**

- Transitioned w/ VTR to NP33 at NAVO
- OPTTEST completed within TODS infrastructure using AOPS v4.0 products

### **- BioCast v1.0**

- Integration into TODS infrastructure.
- Initial testing using multiple resolution satellite imagery (100m - 1km) and NAVO model data (500m - 3km).
- Running in real-time / operationally for the MissBight / NGOM Test Bed using 1km MODIS combined with 3km RELO-NCOM AMSEAS
- Initial comparisons between OpCast v2.0 and this new 3D advection scheme
- BioCast v1.0 have been made. Preliminary results show forecast
- Transition/Upgrade and VTR scheduled for July 2012 (Q3/4) (In Progress).

## **TODS - End-to-End Validation during MIW Fleet Demonstration (VULCANEX 11-1)**

- Ocean optical forecast was used for “first time” in HARP MIW exercise for determining tow altitude for AQS-24 (imaging system).
- Successful forecasting of the EO performance field and validation of mine target detection (100% of mine targets at suggested tow altitudes identified).



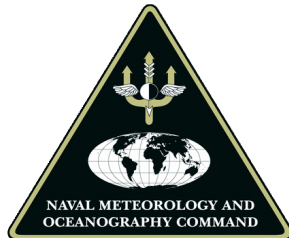
# MIW Fleet Demonstration Summary



- Ocean Optical Forecast was used for “first time” in HARP exercise for determining Tow altitude for ASQ-24 (imaging system).
- First end-to-end test/demonstration/validation of the Nowcast/Forecast capabilities of TODS for AQS-24 operational support for system performance.
- Successful forecasting EO performance field and Validated with Mine target detection (100% of mine targets at suggested tow altitudes identified).
- Squadron requests additional forecast products to improve operational and planning.
- Received a very positive feedback letter from NOMWC – Chief Joel Reyes-Rivera “Products were *crucial* to the overall assessment of the squadron’s capabilities and predicted optimal tow heights provided a baseline to brief pilots and air crewman prior to their missions”
- Letters and requirements are in N85.

# 6.2-6.4 RDT&E Reviews

06-08 March 2012  
Stennis Space Center, MS



# Questions?





# Modeling, Sensing and Forecasting Ocean Optical Products for Navy

**Project milestone chart submitted for FY13**



Large Scale Prediction: Global Ocean Forecast System (GOFS) Version 3.0																
	FY12				FY13				FY14				FY15			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Major TRL Milestones			6	7	8		6	7	8	6		7	8			
1. Validate BioCast 3D Advection v1.0(2D Output)			C													
2. Transition BioCast v1.0			S	C												
3. VTR and OPTEST Support				V	0											
4. Validate 3D Optical Volume Generator (3DOG), update swimmer visibility algorithms, and AQS 24 Performance Surfaces w/ Automatic Optimization of Glider Profiles					S	-	C									
5. Transition 3DOG, Performance Surfaces and SV							S	C								
6. VTR and OPTEST Support								V	0							
7. Validate BioCast v2.0 3D Advection w/ integration of 3D Optical Volume (3D Output)									S	-	C					
8. Transition BioCast v2.0											S	C				
9. VTR and OPTEST Support												V	0			
10. TODS Demonstration during Fleet MIW Exercises (BioCast, 3DOG, Performance Surfaces)			D			D				D						
1. Monthly reports	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Budget	\$150				\$365				\$200K				\$50K			



# Summary



## ***HM-HARP Vulcanex 11-1 Fleet Demonstration & Product Validation Panama City, FL (March 30 - April 08, 2011)***

- **First time an ocean optical forecast provided to MCM operations**
- **Demonstrated Nowcast/Forecast capabilities of TODS for AQS-24 op support -system performance**
- **Provided daily optics brief of the environment (Nowcast/Forecast) to HM-14**
- **100% of Mine Targets at suggested tow altitudes identified**
- **Obtained validation data for MCM performance surfaces (Glider, BSP, AQS-24 Snippets)**
- **Fleet Feedback:**
  - **Products were *crucial* to the overall assessment of the squadron's capabilities**
  - **Predicted optimal tow heights provided a baseline to brief pilots and air crewman prior to their missions**
  - **Correlation to post-mission BSP resulted in similar water column assessment**
- **Products were user friendly and provided useful and reliable information for mission planning and assessment**
- **Fleet/HM requested these products for future exercises (Future Op Requirement)**
- **Received a very positive feedback letter from NOMWC - Chief Joel Reyes-Rivera**